Development of a stream water temperature model as a component model for OpenMI based integrated modelling of river Zenne, Belgium.

Narayan Kumar Shrestha[a,*], Olkeba Tolessa Leta[a], Jiri Nossent[a], Ann van Griensven[a,b], Willy Bauwens[a].

[a]Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium.
[b]UNESCO-IHE Institute for Water Education, Core of Hydrology and Water Resources, The Netherlands.

*Corresponding author. Tel.: +32 (0)2629 3036; fax: +32(0)2629 3022. E-mail: nashrest@vub.ac.be

Introduction: In 2000, the European Union launched the Water Framework Directive (WFD) (EU, 2000), which calls to achieve a good ecological status of all water bodies by 2015 through integrated river basin management. Integrated models are therefore necessary to serve as tools for river basin management in the scope of the WFD. Despite large investments made for the management of the Brussels' sewer systems, the Zenne river still receives high loads of pollutants, especially considering the small size of this receiving water body. An interuniversity, multidisciplinary research project 'Good Ecological Status of the river Zenne (GESZ)' was therefore launched to evaluate the effects of the wastewater management plans in the river basin on the ecological functioning of the river. Hereto, we considered different water quantity and quality processes the hydrology in the river basin, the hydraulics in the river and in the sewers, erosion and sediment transport, the Carbon-Nitrogen-Phosphorus (C-N-P) cycle, the transport of trace metals and the transport and decay of the faecal indicator bacteria. To this purpose, we used different models (based on existing as well as on new simulators). These simulators needed to be integrated, in view of a holistic analysis of the basin. We decided to opt for the Open Modelling Interface – OpenMI (Moore and Tindall, 2005) to build various integrated models.

The water quality model's parameters, such as the kinetic parameters of the C-N-P model, the faecal bacteria decay rate, are dependent on temperature. While the importance of the stream water temperature is generally acknowledged, it is worth mentioning that 'temperature is probably the most important, but least discussed, parameter in determining water quality' (Blakey, 1966). Hence, it is important to develop a simple, yet robust stream water temperature model in order to integrate it with the different water quality models.

This paper discusses the development of a stream water temperature model which is intended to be used as a component model for integrated modelling of river Zenne.

Materials and methods: Several factors affect the stream temperature (Caissie, 2006), such as atmospheric conditions, topography, stream discharge and streambed conditions. Accordingly, a predictive model should consider all of these factors, including all the heat exchanges between air/water and in riverbed/water interfaces. Such consideration would eventually lead to a complex mathematical formulation and a very significant data demand. A complex model structure also means longer calculation times, which could be a bottleneck if the model is sought to be used as a component of an integrated modelling chain. Hence, there have been attempts in recent times to develop simpler models, by considering predictive relationship between the air and the stream temperature only. One of such relationship, as suggested by (Mohseni et al., 1998) is:

$$T_s = \mu + \frac{\alpha - \mu}{1 + e^{\gamma(\beta - T_a)}} \qquad (1)$$

where *Ts* is the stream water temperature, *Ta* is the air temperature, μ is the minimum stream temperature (^{o}C), α is the maximum stream temperature (^{o}C), γ is the steepest slope at the inflection point of the *Ts* function plotted against *Ta* (-) and β is the air temperature at the inflection point of the *Ts* function plotted against T_a (^{o}C).

Because of the robustness of such logistic-type non-linear regression model (Caissie, 2006; Mohseni et al., 1998; Morril et al., 2005), we opted for the relationship (Eqn.1) to develop stream water temperature model.

We used the popular variance-based Sobol' method (Sobol', 1990) to determine the sensitivity of the stream water temperature to the variation of the parameters. To infer posterior distributions of the parameters, we used a Markov Chain Monte Carlo (MCMC) sampler $\text{DREAM}_{(ZS)}$ (Vrugt et al., 2009). For this, we used stream water temperature data (recorded in a frequency of once a month) of 1990-2010 of four VMM stations upstream of Brussels and daily mean air temperature data recorded by the RMI at Ukkel. In a final step, the optimized parameters were validated in an OpenMI based integrated model consisting SWAT, SWMM and the temperature model itself.

Results: The total sensitivity - S_{Ti} plot (Fig.1) clearly indicates that the parameter 'β' is the most sensitive parameter and the parameter 'γ' - the least sensitive parameter. For all parameters, model evaluation of about 6000 showed a quasi-static value of $S_{Ti.}$

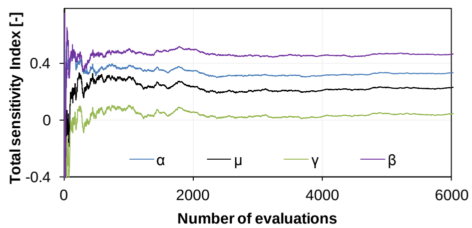

Figure 1: Evolution of S_{Ti} for the four parameters of the model

The marginal posterior distribution of the parameters (Fig.2) shows that the parameters are well defined within the specified range by $DREAM_{(ZS)}$. Comparatively, the parameter 'μ' showed wider dispersion. However, the dispersion is very small.

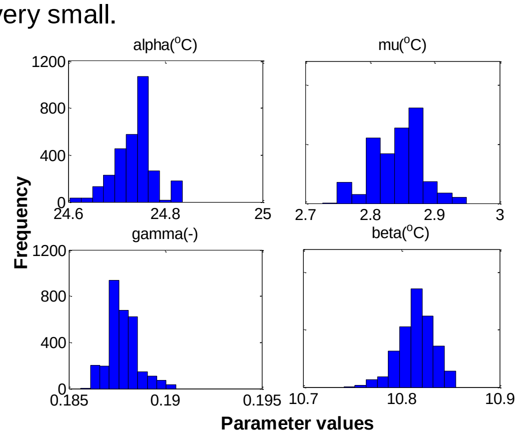

Figure 2: Posterior distribution of parameters for the last 5000 sample size

The stream water temperature model result of the integrated model in OpenMI (Fig.3) shows the predictive capability of the model. As can be seen, the model reproduced the trend of observation well, and based on the performance rating criteria defined in (Shrestha et al., 2013), the model results are 'Very Good'.

The validated model has been used as a component model in various OpenMI integrated models of the river Zenne. It is used to simulate sediment dynamics (Shrestha et al., 2013), faecal bacteria dynamics (Shrestha et al., In Press) and in-stream water quality processes (Leta et al., In Press).

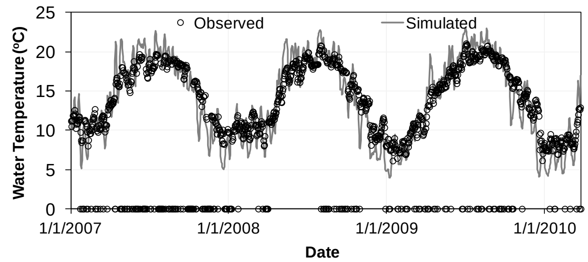

Figure 3: Simulated and observed daily stream water temperatures at FlowBru station N02Missing observations are shown as 0°C.

Conclusions: We performed sensitivity analysis, optimized parameters of the the non-linear stream water temperature model. The temperature model is then integrated with SWAT and SWMM in OpenMI platform. Results showed that such regression model can be used as a component model to form various OpenMI based integrated models.

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